Magnet Technology

T2

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The T2 Working Group has reviewed and discussed the issues and challenges of a wide range of magnet technologies; superconducting magnets using NbTi, Nb_3Sn and HTS conductor with fields ranging from 2 to 15 Tesla and permanent magnets up to 4 Tesla. The development time of the various technology options varies significantly, but all are considered viable, providing an unprecedented variety of choice that can be determined by a balance of cost and application requirements.

One of the most significant advances since Snowmass '96 is the increased development and utilization of Nb_3Sn. All of the current US magnet programs, BNL, FNAL, LBNL and Texas A&M have programs using Nb_3Sn. There are also active programs in HTS development at BNL, TAMU and LBNL. A DOE/HEP sponsored program to increase the performance and reduce the cost of Nb_3Sn is in the second year. The program has already made significant improvements. The current funding for this program is $500k/year and an increase to $2M has been proposed for FY02.

Progress in the magnetic properties of permanent magnet materials has been impressive. Materials such as Sm_2C0_{17} and new types of $Nd_2Fe_{14}B$ have a maximum energy product of 240 – 400 kJ/m^3. High field magnets made from these materials have applications as high gradient, adjustable quadrupoles for the NLC, injection line, correctors and Lambertsons for a VLHC and damping ring magnets and wigglers. R&D is directed towards improving the thermal and radiation stability, adjustable strength with high magnetic center stability and hybrids for improved stability and use as accelerator magnets. A combination of declining costs and improved materials has made permanent magnets competitive with conventional and superconducting magnets in many applications.

A majority of the discussion at Snowmass focused on magnets for large colliders. As one of the major accelerator components, they are significant cost drivers.

A superferric magnet for a proposed VLHC has been described in the VLHC Design Report. It has a maximum field of 2T generated by a 100 kA, superconducting transmission-line. A couple of alternative designs were discussed which offer more freedom in the choice of parameters. The Texas Accelerator Center (TAC) magnet was proposed for the SSC. Several of these long magnets were built and successfully tested. Relative to the FNAL transmission-line magnet, they have a larger bore (2.5 cm X 3.5 cm compared to 1.8 X 3.0 cm) and higher field, 3T. The multiple current powering scheme employed to cope with saturation effects may provide a means of extending the dynamic range, allowing consideration of a first stage VLHC with 50 TeV center-of-mass energy in a smaller ring while still retaining the Tevatron as the injector. This magnet will require a more extensive cryogenic system and beam screen at the luminosities and energies under discussion. At the time of the SSC, the multiple power supply requirement was considered a drawback, but power supply technology has progressed significantly since that time, making the TAC magnet, or some variation of it, a possible candidate for an inexpensive collider dipole. During the workshop, a couple of hybrid superconducting/permanent magnet designs were discussed. It was agreed that the next steps following the workshop would be to make a detailed cost comparison of the TAC and Transmission-line magnets and to consider a new design, combining some of the features of the proposed alternatives.

A small-bore, 5 Tesla, NbTi magnet, based on the RHIC dipole was discussed. It was agreed that magnets in this field range merit further study. Medium field magnets allow more flexibility in the choice of machine parameters and overall may lead to a less expensive accelerator.

The recent success of a 14.7 Tesla dipole built by LBNL and the 11 Tesla development program at FNAL has expanded the field range that can be considered for accelerator dipoles. The disadvantages of high field magnets and Nb_3Sn, such as synchrotron radiation loads on the cryo system, high cost and magnetization effects are being addressed. Schemes have been proposed to eliminate the required beam screens by using photon stops, which would allow the use of a smaller bore. Several schemes have been proposed to significantly reduce persistent current effects due to the large filaments and high current density of Nb_3Sn. The recent results have been promising, but high field magnet technology will need some innovative new ideas in order to meet cost reduction requirements. Success can only be achieved through an aggressive, focused magnet development program. Low-cost, high-performance magnets will eventually be required. There are no alternatives to high field magnets in an upgrade scenario. The machine energy is ultimately determined by the dipole field strength.

The greatest technical challenges are the Interaction Region quadrupoles for both linear and circular colliders. Both superconducting and permanent magnets are being considered for use in IR's for Linear Colliders. While the gradients are fairly modest, the requirements on stability are extremely challenging. IR quadrupoles for hadron colliders require large gradients (300 – 600 T/m), large bores and excellent field quality. Heat loads are very high; 600 W/side for the Stage-1 VLHC. These conditions, if not mitigated, will favor the use of HTS, should it become available, and/or higher performance A15's.

The US magnet R&D programs have not totally recovered from the demise of the SSC. The resources required to bring the existing magnet technology options to a point where they can be reliably costed and considered for use in a collider design, does not currently exist. In addition to increased R&D funding, there is need for a global cost framework to compare and evaluate design options. Since the RHIC dipoles are the only US example of industrial procurement, it is suggested that those costs can be used as a basis to develop a comparative cost model. The magnet programs need to work closely with accelerator physicists to push all parameters to the limit and arrive at the most cost-effective combination of magnet design, machine performance and risk. There has been informal activity in this direction, for example, at the VLHC Workshops, but there is a need to formalize this activity in a more coherent way.